

THE EFFECTS OF NITINOL STENT OVERSIZING IN PATIENTS UNDERGOING FEMORO-POPLITEAL ARTERY REVASCULARIZATION: A GEOMETRICALLY PATIENT-SPECIFIC FINITE ELEMENT STUDY

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INTRODUCTION

Nitinol stent oversizing is commonly performed during endovascular procedures; however, currently, stent sizing mostly relies on the expertise of the clinicians and is not defined by objective criteria. While oversizing a stent will undoubtedly increase acute luminal gain, it can also create a hostile chronic environment for the artery through stent-to-arterial wall interactions, which may ultimately lead to arterial damage, neointimal hyperplasia and restenosis.

Previous clinical studies reported controversial findings on the clinical outcome of stent oversizing. Therefore, a better description of the biomechanical implications of oversizing on arterial tissues may help to understand the mechanisms responsible for restenosis and help the clinicians select the appropriate stent size during intervention. The aim of the present study was to quantify the effects of Nitinol stent oversizing using numerical models of healthy and calcified femoro-popliteal (FP) arteries obtained from patients undergoing endovascular revascularization.

METHODS

The anatomies of the FP arteries of five patients were obtained via 3D rotational angiography. Finite Element (FE) models of healthy and calcified arteries were reconstructed around arterial centerlines. The tissue was modelled as hyperelastic with properties corresponding to popliteal arteries [Gasser, 2006]. Damage models for the calcification included plastic deformation and stress softening.

Deployment simulations of two different Nitinol stents, with diameters ranging from 5.5 to 9 mm, were performed. For diseased arteries, the simulations also included the clinical steps to crack the calcification prior to stenting. Arterial stresses, luminal gains and fatigue behavior of the stents were analyzed. Furthermore, computational fluid dynamics methods were used to simulate the physiological blood flow inside the stented healthy arteries to obtain wall shear stress (WSS) parameters.

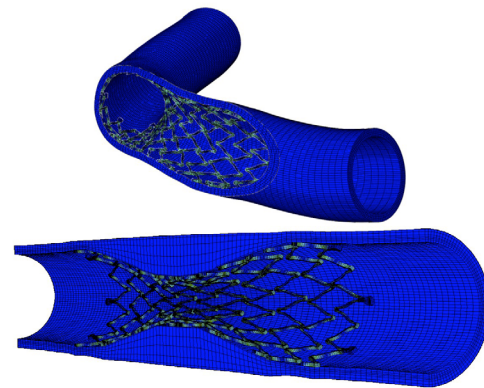


Figure 1: Cut-views of a stent expansion in a healthy, patient-specific artery (top) and a calcified artery (bottom)

RESULTS

For healthy arteries, adventitia was found to be mechanically predominant, as well as the most failure-prone arterial layer. For all cases, the maximum circumferential stresses in this layer increased non-linearly with respect to the unconstrained stent diameters. Increasing the oversizing ratio from 1.1 to 1.8 led to a 4.5% increase of the lumen and a 66% increase of the wall stresses. A gradual decrease in the safety factor of the stent was found with increased oversizing (5.28 ± 0.1 to 1.18 ± 0.11). Blood flow simulations showed that localized areas affected by low WSS increased with higher oversizing ratios and use of the stiffer stent.

DISCUSSION

Stent oversizing increases the risks of chronic irritation of the structural and hemodynamic properties of the popliteal arteries. The damage inflicted onto the arterial walls and continuous degradation caused by critical flow parameters may create circumstances for restenosis. Our numerical model indicates that a maximum oversizing ratio of 1.1 is recommended for the healthy FP arterial tract. On the other hand, the predominant arterial layer and the stress distribution in the arteries change drastically with the inclusion of calcification. These changes showcase the importance of modeling the calcified layer, which can directly impact the appropriate oversizing ratio.

REFERENCES

- Gasser et al, *J R Soc Interface*, 3:15–35, 2006.